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DEVELOPMENT OF ULTRA-THIN FILM PRESERVATIVE COMPOUNDS

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Prepared under Navy, Bureau of Naval Weapons

Contract NOw 63-0293-c

QUARTERLY REPORT No. 3

Covering Period: 1 May 1963 through 31 July 1963

FOSTER D. SNELL, INC.

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FOSTER D. SNELL, INC
29 W. 15th St., N.Y. 11, N.Y.

This report applies

to work on:

Contract NOw 61-0855c

ABSTRACT

Films, when applied from solutions which have aged for several weeks, appear to afford better corrosion protection to metals (based on results from testing in the controlled cyclic condensation humidity cabinet) than do films applied from more freshly prepared solutions.

Half-Second Butyrate films modified with a dehydrated castor alkyd have better adhesion to metal surfaces than do unmodified films, but inclusion of nonyl phenoxy acetic acid in the formulations again results in poor adhesion. No success has been achieved in efforts to improve the adhesion of Acryloid B-72 films thus far.

Falex wear test data fail to indicate any pattern of lubricative differences of various films which might be related to formulation variations.

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I. INTRODUCTION

Compositions based on Acryloid B-72, Half-Second Butyrate, Epon 1007 and Piccopale 100 evaluated as thin-film corrosion preventive compounds in the controlled cyclic condensation humidity cabinet have shown some degree of effectiveness. Unmodified films of Acryloid B-72 and Epon 1007 fairly effectively prevented corrosion under the humidity cabinet test conditions and were further improved in this respect by the addition of some corrosion inhibitors. Armeen C, a heterocyclic tertiary amine, improved the corrosion prevention ability of Epon 1007 films but was not particularly effective in other films tested. The effectiveness of both acrylic and epoxy films as corrosion preventive compounds was enhanced by the inclusion of nonyl phenoxy acetic acid.

Both Piccopale 100 and Half-Second Butyrate films, unmodified, were comparatively ineffective as corrosion preventives - particularly ineffective were the Piccopale 100 films. Modification of Piccopale 100 films with Alox 2028 (a mixture of oxy acids and esters derived from oxidation of petroleum fractions which contains a small amount of a sulfonate inhibitor) resulted in a very effective corrosion preventive. Nonyl phenoxy acetic acid proved to be beneficial in improving the protection from attack afforded by Half-Second Butyrate films.

Armeen C, Alox 2028, and nonyl phenoxy acetic acid were all quite effective as corrosion preventives but lacked the necessary film qualities to be acceptable materials for the solution of the present problem. Films in which nonyl phenoxy acetic acid is employed have generally poor adhesion. In films formed from Piccopale 100 - Alox 2028 mixtures, small blisters and some haziness is evident after several days in the test chamber.

In order to further improve these films, small amounts of polyvinylpyrrolidone, tetraisopropyl titanate and silicone oils were added in these formulations. Acetate - butyrate formulations were modified with FCD-555B (a dehydrated castor alkyd) and acrylic formulations were also modified with Acryloid C-10LV (a flexible, tacky acrylic polymer with better adhesion qualities than Acryloid B-72).

Effectiveness of materials was evaluated by testing steel, copper and brass panels, coated from test solutions, for 7 days in the controlled cyclic condensation humidity cabinet. Conditions of temperature and humidity and timing cycles were maintained the same as they had been in earlier testing. Effects on lubricant properties were studied thus far with Falex Lubricant Tester three-hour wear test.

II. EFFECTIVENESS OF CORROSION PREVENTION IN CYCLIC CONDENSATION HUMIDITY CABINET

There was little improvement in effective corrosion protection obtained with films from the newer compositions being reported during the current period. Some composition changes resulted in drastically poorer protection than was previously obtained with similar films. This was particularly true of modifications of epoxy and hydrocarbon (Epon 1007 and Piccopale 100) resin compositions. Some slight improvements were noted with acrylic and acetate butyrate compositions, but there were no dramatic improvements achieved.

From the results obtained in this testing period, copper and brass surfaces appear to present less of a protection problem than do steel surfaces. Acrylic and epoxy films appeared particularly effective.

A. PICCOPALE 100 - ALOX 2028 COMPOSITIONS.

Piccopale 100 compositions which had been shown previously to give films which protect steel quite well under the conditions of testing were modified in order to improve some of the characteristics of these films. In film thicknesses of 0.2 mils, composition #39 (Piccopale 100 - 75 pbw; Alox 2028 - 25 pbw) allowed only minor pitting to occur on steel panels after 7 days exposure in the controlled cyclic condensation humidity cabinet. However, these films were, after 4 or 5 days exposure, uniformly covered with very small blisters which markedly reduced the clarity of the films and made inspection of the panels difficult. To correct this condition and perhaps achieve at least equivalent protection at even thinner film thicknesses, several changes were made to this composition.

The ratio of Alox 2028 to Piccopale 100 was untouched, but in compositions 77 through 79 and 91 through 97 the solvent was changed from a 90:10 Toluene-Butanol mixture (Piccopale formulations 39 and earlier) to a 60:40 Xylol:Mineral Spirits mixture. This was to slow down the evaporation rate and prevent "skinning over" of the Piccopale film to reduce chances for solvent entrapment. This was thought to be one possible cause of the blistering observed in these films.

All corrosive attack observed on panels protected with Piccopale compositions had begun as very fine pitting which grew steadily larger and more numerous. If this condition of failure was the result of moisture penetration of the film, it was hoped that addition of a small amount of silicone oil would make the film surface more repellant to water. In compositions 77, 78, 79, 93, and 94 silicone oils were added in the amount of 0.1 per cent of nonvolatile composition. None of these compositions appeared to result in enhancement of protection.

Advawax P is a high molecular weight polybutene with a melting point of 133-135°F. and Advawax M is a high molecular weight polybutene and an amber colored microcrystalline wax having a melting point of 155°F. These materials reduce moisture vapor permeability of wax films and it was hoped that a similar effect would be achieved in Piccopale 100 films. Compositions 95, 96, and 97 gave films which allowed considerably less pitting than do compositions 91, 92, 93, and 94. In the former compositions 1 per cent by weight of the nonvolatile materials was Advawax M (96) or Advawax P (95 and 97).

In formulations 91 through 97, tetraisopropyl titanate was added to react any residual moisture on the metal surface and form a TiO_2 film which would serve as a base coat for the polymeric film. However, no benefit was observed that could be attributed to the inclusion of this ingredient.

Aging of formulation 78 before application to metal panels resulted in an unlooked for improvement in corrosion protection. Films from a freshly prepared composition (less than one week old) permitted about one-third of the metal surface to be covered with pitting rust. This same composition applied two weeks later resulted in a film which allowed only one-third as much pitting. Still another month later, the same composition when applied gave a film resulting in one-sixth the surface pitting as did the original film. The same effect, to a lesser extent, was noted with acrylic and acetate-butyrate films (70, 71, and 76).

Although improved protection has not been obtained with new Piccopale 100 compositions, there was no longer any evidence of blistering (although solvent entrapment may have occurred as evidenced by "rainbows" in the films) and films appear glossier and clearer after testing than previously. Moreover, the film thicknesses of the newer compositions were less than 0.1 mil as compared with 0.2 mils thicknesses with the older compositions. Hence, with compositions 95, 96, and 97, it might be said that some improvement in corrosion prevention had been obtained.

B. ACRYLOID B-72 COMPOSITIONS.

Acryloid B-72 films which contained 10 per cent by weight of nonyl phenoxy acetic acid (Composition #58; Quarterly Report No. 2) quite effectively protected polished steel panels from rusting when exposed in the controlled cyclic condensation humidity cabinet. These films, however, had very poor adhesion and peeled rather freely with very little effort. This adhesion was notably less than for films of unmodified Acryloid B-72. Changes in the compositions being reported on now were made with concern for the effect they might have on adhesion.

Compositions 70 through 75 and 88 contained a small amount of polyvinyl pyrrolidone which is a good bonding agent on a wide variety of smooth surfaces. Possibly, it could improve the adhesion of these acrylic films to polished steel. Since polyvinyl pyrrolidone is water sensitive, only small quantities were added to these compositions so that the moisture resistance of the films would not be impaired.

Acryloid C10LV is a tacky, flexible acrylic resin which has the best adhesion properties of the family of polymers of this group. Some Acryloid B-72 was replaced with Acryloid C10LV (10 per cent by weight of the acrylic portion of the composition) in formulations 72, 73, 75, and 90.

Titanium dioxide films derived from titanium esters serve as a basis for better adhesion of plastic materials to metal surfaces. Compositions 88, 89, and 90 included some tetraisopropyl titanate in order to affect improved adhesion by this method.

While there was some barely noticeable improvement in adhesion for some films from these new acrylic compositions under some conditions, the changes made in the compositions were generally unnoticeable. Adhesion of some films on brass and copper was somewhat better than for these same films on steel.

These changes, made to effect improved adhesion of acrylic films, did not result in any appreciable change in corrosion protection afforded by films from the previous formulations. Compositions 72, 73, 74, and 75 allowed somewhat greater degree of pitting on test panels than did films from composition 59 (Quarterly Report No. 2). Panels coated with the newer compositions were observed to have 5 to 10 per cent of the surface pitted compared with 1 per cent for those coated with composition 59 (see Quarterly Report No. 2). (As before, per cent of pitting rust under 10 per cent is estimated as one-fourth of number of small pits observed.) However, the film thickness of coatings from compositions 70 through 75 and 88 through 90 averaged less than 0.1 mil while earlier film thicknesses were in the neighborhood of 0.2 mils. Compositions 88 through 90, all containing tetraisopropyl titanate, deposited films on panels which allowed 5 to 10 small pits.

Films applied from formulations 70 and 71 exhibited similarly improved properties to those accomplished by films applied from composition 78 (Piccopale 100 - Alox 2028). That is, films applied from "older" solutions appeared to give better protection than those applied from "fresh" solutions. Perhaps, because of the lesser degree of attack on the acrylic films, this effect was not so pronounced as that observed with composition 78. Adhesion of these films also appeared to have been somewhat improved by "aging" the solutions from which they were applied.

Generally, properties of acrylic films applied from the newer compositions have not been altered from those of films applied from earlier compositions.

C. HALF-SECOND BUTYRATE COMPOSITIONS.

Half-second butyrate composition films (Code 53, Quarterly Report No. 2) containing 10 per cent nonyl phenoxy acetic acid were equivalent to similar acrylic films in corrosion protection properties and similarly exhibited rather poor adhesion to polished steel surfaces. To improve this condition of poor adhesion, formulations 76, 98, 99, and 100 were prepared. Basically, this change in composition was the addition of a dehydrated castor alkyd (FCD555-B) which has been used to improve adhesion of acetate-butyrate films on metal previously. Tetraisopropyl titanate was also included in composition 100, while in composition 98, nonyl phenoxy acetic acid was omitted.

Adhesion of films applied from compositions 76, 99, and 100 was not improved, while composition 98 films (in which there was no nonyl phenoxy acetic acid present) had appreciably better adhesion than the other acetate-butyrate films. Adhesion of formula 76 films on brass and copper was somewhat better than these films had shown on steel surfaces (as was the case with acrylic films).

Corrosion protection afforded by these various compositioned films was equivalent, all films protected steel from rusting quite well.

D. EPON 1007 COMPOSITIONS.

Previous testing indicated that Armeen C, nonyl phenoxy acetic acid and Glycomul MA appeared to enhance the effectiveness of Epon 1007 films as corrosion preventives. Several of these films, particularly those compositions containing Glycomul MA, became whitened when exposed in the humidity cabinet. To lessen moisture, contact angles and penetration of these films and thereby reduce their tendency to whiten, silicone oils were incorporated in these epoxy formulations (Codes 80 through 84).

In compositions 81 through 84, the effect of silicone oil was to make the solutions autophobic. The silicone was selectively adsorbed onto the metal surface from solution and consequently presented a low energy surface for the remainder of the solution to wet. With the silicone removed, the remainder of the solution did not have sufficiently low surface tension in order to spread on the adsorbed silicone film. This condition was evidenced by considerable "watering" or "eyering" of films applied from these compositions. As a result, compositions 81 through 84 films could not prevent corrosive attack on large areas of uncoated metal surface when test specimens were exposed in the cyclic condensation humidity cabinet.

The autophobic condition of compositions 81 through 84 was not evident with composition 80. However, protection afforded by composition 49 films (no silicone present) appeared slightly better when applied on steel surfaces than was the protection obtained with composition 80 films. On brass and copper surfaces, contrary results were obtained - the composition 80 films appearing to afford better protection.

The adhesion of these Epon 1007 composition films is poorer than should be the case for epoxy resin films and these films also seem too brittle. It would appear that plasticization of these compositions would be a necessary modification.

III. THREE-HOUR FALEX WEAR TESTS

Test pins and blocks of the Falex Lubricant Testing Machine were coated with several of the compositions prepared and three-hour wear tests were run on these parts. The pin and blocks were immersed in an oil bath maintained at 175°F., and the pin was rotated at 290 rpm between the two V-shaped bearing blocks. The V-shaped bearing blocks are inserted in two lever arms which constitute a load applying mechanism. A load of 120 pounds was maintained during the test. Load is applied by turning an attached ratchet wheel which serves as an accessory wear measurement device. The amount of wear on the test pin is determined by scribing the ratchet wheel at the beginning of the test while the test pieces are under a constant load and recording the number of teeth that are taken up to maintain this load over the three-hour test period. Each tooth of the ratchet wheel taken up is equivalent to 0.0000556 inches of wear.

Five of the compositions when applied appear to reduce the total wear of the pins compared with the wear of uncoated pins and blocks. Three of these are Piccopale compositions, (39, 91 and 97), one an acrylic composition (89), and one an acetate-butyrate composition (100). There has been an insufficient amount of this testing to discover any patterns and draw any sort of conclusions from the results obtained.

IV. SUMMARY AND CONCLUSIONS

During the current quarter, ultra-thin film preservative compositions previously shown to have promise were further modified in order to improve some of the deficient properties of these compositions. Generally, these formulation changes have not produced the results desired, although many of these compositions appear to be satisfactory corrosion preventives.

The blistering which was observed with exposed Piccopale 100 composition films previously has been eliminated, but these modified compositions generally give poorer protection. Exceptions are compositions 95, 96, and 97 which appear to give protection equivalent to that obtained in the older composition (39) and with thinner films. These compositions all contain a small amount of a high molecular weight polybutene which may have the effect of reducing the moisture vapor permeability of these films.

Acrylic composition films had been deficient in regard to the adhesion of these films to polished steel. This deficiency still exists after modification of compositions with Acryloid C-10LV, polyvinyl pyrrolidone and tetraisopropyl titanate. It appears that nonyl phenoxy acetic acid is the chief cause of the poor adhesion of these films.

With acetate-butyrate compositions, the adhesion of films was improved when nonyl phenoxy acetic acid was eliminated and a dehydrated castor alkyd, FCD555-B, included in the formulation. This composition (98) corresponds to a widely used clear metal lacquer for coating aluminum, silver, brass and steel and other metals likely to tarnish.

Several epoxy resin compositions (81-84) modified with silicone oils became autophobic as a result of this change and were unable to yield integral films which could protect metals from rusting. It appears that epoxy resin composition films need plasticization since these films are quite brittle.

Three-hour Falex wear tests were run on pins and blocks coated with several of the corrosion preventive compositions. However, the data thus far is insufficient to warrant any interpretations.

Aging of several of these solutions appears to have resulted in improved film properties, particularly with regard to corrosion prevention. This was an unlooked-for result of these investigations and this phenomena is not being analyzed further unless further corroborative evidence is adduced. Generally, films have been applied from solutions which were comparatively freshly prepared - that is, one to two weeks old at the time of application.

V. FUTURE WORK

Further modification of Piccopale 100 - Alox 2028 compositions will follow the line suggested by the results obtained with the addition of the polybutene compounds (Codes 95, 96, and 97). Acetate-butyrate compositions based on formula 98 as a starting point will be investigated further. Plasticization of Epon 1007 compositions with chlorinated biphenyls (such as Aroclors 1248 and 1254) and other non-reactive diluents will be pursued in an effort to improve these compositions.

Respectfully submitted,

FOSTER D. SNELL, INC.

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August 27, 1963

VI. RESULTS OF TESTS

Table I

RESULTS OF CORROSION TESTS

Code	Film Composition (parts by weight)		Test Metal	Environment (Length of test) days	Condition of Test Panel		Age of Solution at time of Application
					% Surface Affected	Type of Attack - Remarks	
39	Picco ale 100 Alox . 028	75 25	Steel	C (7)	4	Occasionally pitted Film appears dulled	13 weeks
39			Steel	C (7)	4	"	17 weeks
39			Copper	C (7)	2	Occasional small area of discoloration Film dulled and water spotted	13 weeks
39			Brass	C (7)	1	Rare points of discoloration Film dulled and water spotted	13 weeks
77	Picco ale 100 Alox : 028 Poly nyl- pyr olidone DC-7: 0	74.53 24.81 0.51 0.15	Steel	C (7)	60	Completely pitted, pits starting as very small and gradually growing larger. No pitting in evidence until third day of test.	1 week
78	Picco alc 100 Alox 2)28 Polyvi ayl- pyrr olidone DC-20) (5 cps)	74.53 24.81 0.51 0.15	Steel	C (7)	33	Generally pitted, pits start small and grow larger. No pitting in evidence until third day.	1 week
78	"		Steel	C (7)	11	Occasional pits - which tend to cluster and grow.	3 weeks
78	"		Steel	C (7)	5	Occasional pits which grow	7 weeks
78	"		Copper	C (7)	4	Several small areas of discoloration	3 weeks

RESULTS OF CORROSION TESTS

Code	Film Composition (parts by weight)		Test Metal	Environment (Length of test) days	Condition of Test Panel % Surface Affected	Condition of Test Panel Type of Attack - Remarks	Age of Solution at time of Application
73	"		Brass	C (7)	5	Very tiny specks of discoloration	3 weeks
79	Piccopale 100 Alox 2028 DC-10	74.91 24.94 0.15	Steel	C (7)	50	Generally pitted - starting small, growing gradually.	1 week
91	Piccopale 100 Alox 2028 Tetraisopropyl-titanate	74.25 24.75 1.00	Steel	C (7)	35	Generally pitted - pits clustered and growing gradually.	2 weeks
92	Piccopale 100 Alox 2028 Tetraisopropyl-titanate	73.50 24.50 2.00	Steel	C (7)	30	" (see 91)	2 weeks
93	Piccopale 100 Alox 2028 Tetraisopropyl-titanate DC-200(200 cstk)	74.17 24.73 1.00 0.10	Steel	C (7)	20	" (see 91)	2 weeks
94	Piccopale 100 Alox 2028 Tetraisopropyl-titanate Polyvinyl-pyrrolidone DC-200(200 cstk)	73.99 24.67 1.00 0.25 0.10	Steel	C (7)	10	Scattered pitting tending to cluster and grow.	2 weeks
95	Piccopale 100 Alox 2028 Tetraisopropyl-titanate Advawax P	73.50 24.50 1.00 1.00	Steel	C (7)	5	Scattered pitting - generally small	2 weeks

RESULTS OF CORROSION TESTS

Code	Film Composition (parts by weight)		Test Metal	Environment (Length of test) days	Condition of Test Panel: % Surface Affected	Condition of Test Panel: Type of Attack - Remarks	Age of Solution at time of Application
96	Piccopale 100 Alox 2028 Tetraisopropyl-titanate Advawax M	73.50 24.50 1.00 1.00	Steel	C (7)	5	Scattered pitting - generally small	2 weeks
97	Piccopale 100 Alox 2028 Tetraisopropyl-titanate Advawax P Polyvinyl-pyrrolidone	73.31 24.44 1.00 1.00 0.25	Steel	C (7)	3	Occassionally pitted - small pits	2 weeks
70	Acryloid B-72 Nonylphenoxy acetic acid Polyvinyl-pyrrolidone	89.55 9.95 0.50	Steel	C (7)	5	Scattered pitting -small Poor adhesion	1 week
70	"		Steel	C (7)	2	Occasional pitting - small Fair adhesion	3 weeks
70	"		Steel	C (7)	2	Occasional pitting - small Fair adhesion	7 weeks
70	"		Copper	C (7)	0	Fair to good adhesion	3 weeks
70	"		Brass	C (7)	0	Fair to good adhesion	3 weeks
71	Acryloid B-72 Nonylphenoxy acetic acid Polyvinyl-pyrrolidone	89.78 9.97 0.25	Steel	C (7)	6	Scattered pitting - small Poor adhesion	1 week

RESULTS OF CORROSION TESTS

Code	Film Composition (parts by weight)	Test Metal	Environment (Length of test) days	Condition of Test Panel: % Surface Affected	Condition of Test Panel: Type of Attack - Remarks	Age of Solution at time of Application
71	"	Steel	C (7)	4	Occasional pitting - small Poor to Fair Adhesion	3 weeks
71	"	Steel	C (7)	3	Occasional pitting - small Fair adhesion	7 weeks
71	"	Copper	C (7)	0	Fair to good adhesion	3 weeks
71	"	Brass	C (7)	0	Fair adhesion	3 weeks
72	Acryloid B-72 80.01 Acryloid C10LV 8.94 Nonyl phenoxy acetic acid 9.95 Polyvinyl-pyrrolidone 0.50	Steel	C (7)	8	Scattered pitting - small Fair adhesion	1 week
73	Acryloid B-72 80.81 Acryloid C10LV 8.97 Nonyl phenoxy acetic acid 9.97 Polyvinyl-pyrrolidone 0.25	Steel	C (7)	9	Scattered pitting - small Fair to Poor Adhesion	1 week
74	Acryloid B-72 89.40 Nonylphenoxy acetic acid 9.94 Polyvinyl-pyrrolidone 0.51 DC-200(5 cstk) 0.15	Steel	C (7)	9	Occasional pitting - small Some tendency for rust to creep Poor adhesion	1 week

RESULTS OF CORROSION TESTS

Code	Film Composition (parts by weight)		Test Metal	Environment (Length of test) days	Condition of Test Panel: % Surface Affected	Condition of Test Panel: Type of Attack - Remarks	Age of Solution at time of Application
75	Acryloid B-72 Acryloid C10LV Nonylphenoxy acetic acid Polyvinyl-pyrrolidone DC-200(5 cstk)	80.47 8.93 9.94 0.51 0.15	Steel	C (7)	6	Scattered pitting - small Poor adhesion	1 week
88	Acryloid B-72 Nonylphenoxy acetic acid Tetraisopropyl-titanate Polyvinyl-pyrrolidone	89.10 9.90 0.50 0.50	Steel	C (7)	2	Occasional pitting - small Poor adhesion	2 weeks
89	Acryloid B-72 Nonylphenoxy acetic acid Tetraisopropyl-titanate	89.10 9.90 1.00	Steel	C (7)	2	Occasional pitting - small Poor adhesion	2 weeks
90	Acryloid B-72 Acryloid C10LV Nonylphenoxy acetic acid Tetraisopropyl-titanate	80.18 8.91 9.90 1.00	Steel	C (7)	2	Occasional pitting - small Poor adhesion	2 weeks
76	Half-second Butyrate FCD555-B Nonylphenoxy acetic acid DC-200(5 cstk)	79.58 8.65 11.51 0.26	Steel	C (7)	2	Occasional pitting - small Poor adhesion	1 week

RESULTS OF CORROSION TESTS

Code	Film Composition (parts by weight)	Test Metal	Environment (Length of test)days	Condition of Test Panel: % Surface Affected	Condition of Test Panel: Type of Attack - Remarks	Age of Solution at time of Application
76	"	Steel	C (7)	2	Occasional pitting - small Poor adhesion	3 weeks
76	"	Steel	C (7)	1	Few small pits Fair adhesion	7 weeks
7o	"	Copper	C (7)	0	Fair adhesion	3 weeks
76	"	Brass	C (7)	2	Few small areas of discoloration. At discoloration sites, film is embrittled. Fair to good adhesion	3 weeks
98	Half-second Butyrate 90.14 FCD 555-B DC-200	Steel	C (7)	2	Occasional pitting - small Fair to good adhesion	2 weeks
99	Half-second Butyrate 81.13 FCD 555-B 8.82 Nonylphenoxy acetic acid 10.00 DC-200(200 cstk) 0.05	Steel	C (7)	2	Occasional pitting - small Poor adhesion	2 weeks
100	Half-second Butyrate 80.33 FCD 555-B 8.73 Nonylphenoxy acetic acid 9.90 Tetraisopropyl-titanate 1.00 DC-200(200 cstk) 0.04	Steel	C (7)	2	Occasional pitting - small Poor adhesion	2 weeks

RESULTS OF CORROSION TESTS

Code	Filn. Composition (parts by weight)		Test Metal	Environment (Length of test)days	Condition of Test Panel: % Surfacd Affected	Condition of Test Panel: Type of Attack - Remarks	Age of Solution at time of Application
49	Epon 1007 Armeen C	90.00 10.00	Steel	C (7)	1	Very few pits - small Fair adhesion	13 weeks
49	"		Copper	C (7)	1	Occasional spεck of discoloration Poor adhesion	13 weeks
49	"		Brass	C (7)	2	Few small areas of discoloration Poor adhesion	13 weeks
80	Epon 1007 Armeen C DC-200(5 cstk)	89.87 9.98 0.15	Steel	C (7)	4	Scattered pitting - small Fair adhesion	1 week
80	"		Steel	C (7)	2	Occasional pitting - small Poor to fair adhesion	3 weeks
80	"		Copper	C (7)	0	Poor adhesion	3 weeks

RESULTS OF CORROSION TESTS

Code	Film Composition (parts by weight)		Test Metal	Environment (Length of test) days	Condition of Test Panel: % Surface Affected	Condition of Test Panel: Type of Attack - Remarks	Age of Solution at time of Application
80	"		Brass	C (7)	0	Poor adhesion	3 weeks
81	Epon 1007 Nonylphenoxy acetic acid DC-200(5 cstk)	89.87 9.98 0.15	Steel	C (7)	75	Generally pitted - with some areas of general rust Film badly "eyed"	1 week
82	Epon 1007 Nonylphenoxy acetic acid DC-710	89.87 9.98 0.15	Steel	C (7)	60	Generally pitted Film badly "eyed"	1 week
83	Epon 1007 Glycomul MA DC-710	89.87 9.98 0.15	Steel	C (7)	30	Film cracked and became powdery Rust concentrated on areas of film failure and tend to creep	1 week
84	Epon 1007 Glycomul MA Polyvinyl-pyrrolidone DC-710	89.37 9.96 0.51 0.15	Steel	C (7)	85	Film very powdery. Rust began as small pits and grew rapidly to cover panels as film degraded	1 week

C = Controlled Cyclic Condensation Humidity Cabinet

Table II

RESULTS OF FALEX WEAR TEST

Code	Film Composition		Total Wear Gear Teeth	Total Wear Inches	Remarks (age of solution from which film applied)
	None		7	0.0003892	-
	None		11	0.0006116	-
39	Piccopale 100 Alox 2028	75.0 25.0	2	0.0001112	12 weeks
39	"		2	0.0001112	17 weeks
78	Piccopale 100 Alox 2028 Polyvinyl-pyrrolidone DC-200(5 cstk)	74.53 24.81 0.51 0.15	11	0.0006116	2 weeks
91	Piccopale 100 Alox 2028 Tetraisopropyl-titanate	74.25 24.75 1.00	6	0.0003336	2 weeks
93	Piccopale 100 Alox 2028 Tetraisopropyl-titanate DC-200(200 cstk)	74.17 24.73 1.00 0.10	14	0.0007784	2 weeks
95	Piccopale 100 Alox 2028 Tetraisopropyl-titanate Advawax P	73.50 24.50 1.00 1.00	17	0.0009452	2 weeks
97	Piccopale 100 Alox 2028 Tetraisopropyl-titanate Advawax P Polyvinyl-pyrrolidone	73.31 24.44 1.00 1.00 0.25	1	0.0000556	2 weeks

RESULTS OF FALEX WEAR TEST

Code	Film Composition		Total Wear: Gear Teeth	Total Wear: Inches	Remarks (age of solution from which film applied)
70	Acryloid B-72 Nonylphenoxy acetic acid Polyvinyl-pyrrolidone	89.55 9.95 0.50	25	0.0013900	2 weeks
70	"		13	0.0007228	7 weeks
88	Acryloid B-72 Nonylphenoxy acetic acid Tetraisopropyl-titanate Polyvinyl-pyrrolidone	89.10 9.90 0.50 0.50	10	0.0005560	2 weeks
89	Acryloid B-72 Nonylphenoxy acetic acid Tetraisopropyl-titanate	89.10 9.90 1.00	2	0.0001112	2 weeks
76	Half-second Butyrate FCD 555-B Nonylphenoxy acetic acid DC-200(5 cstk)	79.58 8.65 11.51 0.26	16	0.0008896	2 weeks
76	"		10	0.0005560	7 weeks
98	Half-second Butyrate FCD 555-B DC-200(200 cstk)	90.14 9.80 0.06	19	0.0010564	2 weeks

RESULTS OF FALEX WEAR TEST

Code	Film Composition		Total Wear Gear Teeth	Inches	Remarks (age of solution from which film applied)
100	Half-second Butyrate FCD 555-B Nonylphenoxy acetic acid Tetraisopropyl-titanate DC-200(200 cstk)	80.33 8.73 9.90 1.00 0.04	3	0.0001668	2 weeks
49	Epon 1007 Armeen C	90.00 10.00	26	0.0014456	12 weeks

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